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(54) [Invention Name] High Speed Steel Series Cast Iron Containing Graphite and Composite Roll

(57) [Abstract]

[Purpose] To provide a high speed steel type cast iron material that has a low friction coefficient and resists to crack propagation as well as a composite cast iron roll in which the external layer is made from this alloy.

[Composition] The chemical compositions of this graphite containing high speed steel type cast iron are given by (wt %):

C: 1.8---3.6 %, Si: 1.0—3.5 %, Mn:0.1—2.0%, Ni:0.5—10.0%

Cr: 2.0—10%, Mo: 0.1—10%, W :0.1—10%

V, Nb : the total of one or two elements: 1.5—10%, with Fe being the balance.

The above alloy also contains Co: 0.5—10.0 wt%,

or one or two kinds from 0.01—0.5 wt % Al , 0.01—0.5 wt % Ti and 0.01-0.50% Zr

## [Requested Patent Range]

## [Claim 1] Chemical Composition (wt %):

A high-speed steel series cast iron containing graphite with the following composition:  
 C: 1.8—3.6 %, Si: 1.0—3.5 %, Mn: 0.1—2.0%, Ni: 0.5-10.0%, Cr: 2.0—10.0%, Mo:  
 0.1—10%, W: 0.1—10%, a total of 0.5—10% of one or two kinds of V and Nb, and  
 the balance being iron.

[Claim 2] Based on alloy composition in claim 1, the graphite containing high speed series cast iron contains 0.5-10.0 wt % cobalt.

[Claim 3] Based on alloy composition in claim 1, the graphite containing high speed series cast iron contains one or two kinds of Al :0.01—0.5 wt %, Ti: 0.01—0.5 wt%, Zr: 0.01—0.5 wt%.

[Claim 4] Based on alloy composition in claim 1, the graphite containing high speed series cast iron contains 0.01—0.50 wt % boron.

[Claim 5] Use casting method to form the inner surface of the external layer and the inner part of the roll, melting the inner surface of the external layer with the inner part to form a composite roll. The external layer of the above product is formed by the graphite containing high speed steel type cast iron as in claim 1, 2, 3, and 4. The inner part of the roll is made from high toughness cast steel to form the composite roll.

[Claim 6] A method of making the composite roll by forming an intermediate layer between the external layer and inner layer, the intermediate layer metallurgically bonds with both external and inner layers to form a composite. The above external layer is formed by the graphite containing high speed type cast iron in claims 1, 2, 3, and 4. The above intermediate layer is formed by Adamite cast iron. The inner layer of the above composite roll is formed by a high toughness cast steel.

[Claim 7] Composite rolls made according to claim 5 or claim 6, the inner layer can be grey cast iron, spherical cast iron, or graphite steel.

[Claim 8] In claim 6, the chemical composition of Adamite is given as: (wt %)

C: 1.0—2.5%, Si: 0.2—3.0%, Mn: 0.2—1.5%,  
 P < 0.2%, S < 0.2%, Ni 4.0%, Cr < 4.0%, Mo < 4.0%  
 W+V+Nb < 12%, the balance being Fe.

## [Detailed Description of the invention]

[0001]

[Industry Application] The present invention is about graphite containing high speed steel type cast iron as well as a composite roll in which the external layer is formed by the above alloy.

[0002]

[Prior Art] The chemical composition of high speed steel type cast iron for high wear resistant castings, as disclosed in Japan Patent 4-176840, is as follows;

C: 1.0--3.0%, Si: 0.1—2.0%, Mn: 0.1—2.0%, Cr: 3.0—10.0%,  
 Mo: 0.1—6.0%, W: 1.5—10.1%, V+Nb: 3.0—10.0%, the rest is Fe.

Because of  $M_2C$ 、 $M_6C$  and other hard alloy carbides in its microstructure, Mo, W, and V

containing alloy cast iron has excellent high temperature properties, such as excellent wear and seizure resistance required in hot rolling rolls. Therefore, this is an excellent material for the external layer of a composite roll and then metallurgically bonds to a high toughness inner layer or to an intermediate layer a high toughness inner layer.

[0003]

[Problems to be solved]

Cast rolls made from high speed steels require a higher rolling load because of its high friction coefficient, resulting in a poor feeding property and difficult to keep uniform temperature distribution. A good feeding property means it is easy for the rolled material to separate from the roll. If the feeding property is poor, the rolled plate will easily adhere to the roll surface, forming a curved shape to resist plate moving. Under extreme cases, this may cause seizure, overlap of the rolled plate and other surface damage. Furthermore, a high rolling load will result in the formation of micro-cracks on the roll surface, which will propagate into inside of the external layer of the roll and may cause spalling of the surface.

[0004]The present invention is to provide a composite roll using high speed steel as external layer which has a low friction coefficient and also resist to crack-propagation.

[0005]

[Methods used to solve these problems] In present invention, the chemical composition of graphite containing high speed steel type cast iron is (wt %):

C: 1.8—3.6%, Si:1.0—3.5%, Mn: 0.1—2.0%, Ni:0.5—10.0%, Cr:2.0—10%, Mo: 0.1—10%, W: 0.1—10%, V+Nb: 1.5—10%, the rest is Fe.

The following elements can be added to the above alloy;

Co:0.5—10.0wt%, Al:0.01—0.50wt%, Ti:0.01—0.5wt%, Zr:0.01—0.5wt%, B:0.01—0.5wt%

[0006] Furthermore, it is necessary to use an intermediate layer to form bonds between the external layer and intermediate layer and between the intermediate layer and inner layer. The external layer is formed by the above graphite containing high speed steel; the above intermediate layer is formed by Adamite material, and the inner layer is formed by grey cast iron, ductile cast iron or graphite steel. The carbon content in the intermediate layer is 0.05 wt % and silicon is 0.1-1.5%, it is the best to use Adamite material.

[0007]

[Application] Because the existence of hard alloy carbides from Cr, Mo, W, Nb, and V, together with the solid solution hardening of cobalt to the matrix, enhances room and high temperature properties, especially in high temperature resistance. Furthermore, because of the defined range of C, Si, and Ni, graphite will precipitate to 0.1-7.0% in the alloy. The precipitation of graphite can dampen impacting load, stop crack propagation, reduce friction coefficient and increase heat resistance of the roll.

[0008] using the above graphite containing high speed steel type cast iron as the external layer material can provide a better rolling performance with reduced rolling load, less frictional heat,

and improved plastic deformation ability as well as resist to crack propagation. It can also be used as cold rolling rolls due to its excellent heat resistance from graphite in the alloy.

[0009]Moreover, it is possible to use Adamite to form an intermediate layer in order to prevent high alloy to diffuse from external layer into inner layer to reduce its strength. Because of low alloy content in the boundary between the intermediate and inner layer to suppress carbide formation, this can improve the bonding strength between the two layers. On the other hand, Austenite in the external layer can reduce the inner temperature rise to prevent deteriorating the toughness of inner material and also makes it possible to use quenching temperature higher than 1100 C without changing the form of Martensite. In external layer quenching heat treatment there is no excessive residual stress produced, hence this composite roll has an excellent anti-accident property during rolling process.

[0010]Similar to flake type graphite grey iron, ductile iron or graphite steel, the precipitation of graphite in external layer improves its heat conductivity, this can reduce high temperature deformation of the composite rolls in rolling operation. Because of its fairly low elastic modulus the composite roll will flatten in the contact area under overloading condition to reduce the tendency of excessive internal stress.

[0011]

[Example]The reasons for the selected chemical compositions are given as below;  
C: 1.8-3.6%

C primarily combines with Fe and Cr to form  $M_7C_3$  complex type carbide, and will also form MC,  $M_6C$ , and  $M_2C$  type high hardness complex carbides when combining with Cr, Mo, V, Nb, and W. combines with Mo, V, Nb, and W alloy elements. When carbon is less than 1.8 wt %, there is only a small amount of carbides and no graphite formed in the alloy; when carbon is greater than 3.6 wt % there will be too much carbides and graphite to increase the brittleness of the roll material.

[0012] Si: 1.0—3.5%

Silicon is the necessary element to ensure good fluidity and precipitation of graphite. Silicon is less effective when its content is less than 1.0 wt % while deteriorating wear resistance of the roll material when silicon is higher than 3.5 wt % to have graphite area greater than 7% because graphite will become the starting point of wear loss. On the other hand inoculation can be more effective in promoting graphite precipitation when silicon is added before pouring.

[0013] Mn: 0.1—2.0%,

Mn can increase the hardness of the alloy. Moreover, Mn will combine with S to form MnS, which is the necessary element to prevent material brittleness caused by sulfur. Raw material contains about 0.1 wt% Mn, however when Mn is higher than 2.0 wt % it will decrease the toughness of the alloy.

Ni: 0.5—10.0%

The purposes of adding Ni are to improve matrix property and also promote graphite precipitation. There will be not enough graphite formed if nickel is less than 0.5 wt % and, similar to the effect

of silicon, too much graphite will be formed when nickel is higher than 10.0 wt %. Higher nickel content will also increase the amount of residual austenite, which will deteriorate wear resistance even after heat treatment.

[0014] Cr: 2.0—10%,

Together with Fe, Mo, V, and Nb, Cr can combine with carbon to form complex high hardness carbides to increase high temperature wear resistance. Cr in solid solution can improve hardening ability in quenching operation to enhance wear resistance. There is no obvious benefit when Cr is less than 2.0 wt % however, Cr will worsen toughness when higher than 10.0 wt %.

[0015] Mo: 0.1—10%

Similar to Fe, Cr, V, Nb, and W, Mo can easily form  $M_7C_3$ ,  $M_6C$ , and  $M_2C$  type carbides to increase room and high temperature hardness and also wear resistance. There is no obvious effect when the amount of Mo is less than 0.1 wt % while deteriorating toughness when the amount is higher than 10.0 wt %.

[0016] W: 0.1—10%

Similar to Fe, Cr, Mo, V, and Nb, W can easily form complex carbides to increase room and high temperature hardness and also wear resistance. There is no desired improvement in wear resistance when the amount of W is less than 1.5 wt % while deteriorating toughness and also resistance to hot cracking when the amount is higher than 10.0 wt %. On the other hand, W has a high tendency to segregate during centrifugal casting process, therefore, W should be controlled under 10.0 wt %.

[0017]

V and Nb: 1.5-10.0 wt % of the one or two.

Similar to Fe, Cr, Mo, and W, V and Nb can easily combine with carbon to form MC type carbides to increase room and high temperature hardness and also wear resistance. Furthermore, dendrite from MC type complex carbide grows along depth direction to resist matrix deformation, which is benefit to mechanical properties, especially resistance to cracking. V and/or Nb is not effective when the amount is less than 1.5 wt % while deteriorating toughness when the amount is higher than 10.0 wt %. V and Nb will also segregate during centrifugal casting process if the amount is too high.

[0018] Besides the above elements, the rest is iron and inevitable impurities. P and S are inevitably from raw material. It is desirable to control P and S to the minimum level because S and P can increase brittleness of the alloy. P should be less than 0.2 wt % and S less than 0.1 wt %.

In the present invention, Co can be added to 0.5-10.0 wt % and one or two of Al, Ti, Zn, and B can be added to 0.1-0.5 wt % if necessary.

[0019] Co: 0.5—10.0%

Co has a strong effect to improve the matrix property. Co also has a special effect to retard the carbon diffusion and also increase toughness through solid solution in the matrix. Cobalt improves high temperature hardness and wear resistance. Furthermore, cobalt can increase the solubility of carbide forming elements in austenite, resulting in a higher matrix hardness and better oxidation resistance. Cobalt content needs to be greater than 0.5 wt% to achieve these effects, but no further

improvement if cobalt is greater than 10.0 wt % plus cobalt is a very expensive element. Higher cobalt content will also cause uneven carbide distribution during centrifugal casting process. Therefore cobalt should be controlled between 0.5-10.0 wt %.

[0020]

0.01-0.50 wt% for Al, Ti, and Zr.

Al, Ti, and Zr can reduce oxygen content in the melt metal by forming oxides to improve product quality. Meanwhile the formed oxides can act as crystal nuclei to refine microstructure: there is no obvious benefit if the amount is less than 0.01 wt % while there will be too much inclusion if the amount is greater than 0.5 wt %. The purpose of adding Al, Ti, and Zr is mainly to refine microstructure to improve its wear resistance besides the degassing effect.

[0021] B: 0.01—0.5%

B has the degassing effect by combining with oxygen in the melt alloy. The formed oxides can also have the effect of crystal nuclei during solidification to refine microstructure as well as the effect to improving fluidity. In large castings like cast iron rolls, it is still easy to obtain quenched microstructure because of improvement in hardening ability though it is difficult to achieve fast cooling in large castings. No obvious effect if B is less than 0.01 wt % while material becomes brittleness when B is higher than 0.5 wt %.

[0022]The present invention is used as the external layer material in the composite roll. The composite roll is formed by metallurgically bonding the inner surface of the external layer and the inner roll, or using an intermediate layer to form a three-layer composite roll. The inner material can be advanced grey iron, ductile iron, graphite steel, and casting steels or other materials with high toughness. The first three materials with precipitated graphite are more suitable for this application. Similar to the effect of graphite in the external layer alloy, the existence of graphite improves thermal conductivity of the alloy, and this can avoid hot deformation of the roll during rolling process. The Young's modulus of steels with precipitated graphite steels is lower than 19000 kg/mm<sup>2</sup>, Hence the roll material has a better anti-accident property because of the flattening of roll contact area to absorb stress under overloading condition. Furthermore, low temperature quenching can reduce the internal stress in the external layer from heat treatment. The excellent toughness of the external layer material is especially useful in rough rolling rolls. The followings are the chemical compositions of advanced grey iron, ductile iron, and graphite steel. (wt %);

(1) Advanced grey iron:

C:2.5—4.0 wt %, Si: 0.8—2.5 wt %, Mn: 0.2—1.5 wt %, P<0.2 wt %, S<0.2 wt %, Ni<3.0 wt %, Cr<2.0 wt %, Mo<2.0 wt %, W+V+Nb<4 wt %, the balance is iron plus cobalt from external layer or intermediate layer. If there are Al, Ti, and Zr in external layer alloy, these elements will diffuse into inner layer. However, the effects of these trace elements to the properties are negligible. The compositions before pouring decide the compositions after pouring. The grey iron compositions are given below;

[0023]

C:2.5—4.0 wt %, Si: 0.8—2.5 wt %, Mn: 0.2—1.5 wt %, P< 0.2 wt %, S< 0.2 wt %, Ni<3.0 wt %, Cr<2.0 wt %, Mo<2.0 wt %, the rest is iron.

## (2) Ductile iron

C:2.5—4.0 wt %, Si: 1.3—3.5 wt %, Mn: 0.2—1.5 wt %, P<0.2%, S<0.2 wt %, Ni<3.0 wt %, Cr<2.0 wt %, Mo<2.0 wt %. W+V+Nb<4 wt %, Mg: 0.02—0.1 wt %. The rest is iron and cobalt diffused from external layer or intermediate layer. The following example shows chemical compositions before pouring;

[0024]

C: 2.5—4.0 wt %, Si: 1.3—3.5 wt %, Mn: 0.2—1.5 wt %, P<0.2 wt %, S<0.2 wt %, Ni<3.0 wt %, Cr<2.0%, Mo<2.0 wt %, Mg:0.02-0.1 wt %, the rest is iron with impurities.

## (3) Graphite Steel

C:1.0—2.3 wt %, Si:0.5—3.0 wt %, Mn:0.2—1.5 wt %, P<0.2 wt %, S<0.2 wt %, Ni<3.0 wt %, Cr<2.0%, Mo<2.0 wt %, W+ V +Nb<4.0%. The balance is iron and cobalt from external layer or intermediate layer. The following is the chemical compositions before pouring;

[0025]

C:1.0—2.3 wt %, Si:0.5—3.0 wt %, Mn:0.2—1.5 wt %, P<0.2 wt %, S<0.2 wt %, Ni<3.0 wt %, Cr<2.0%, Mo<2.0 wt %. The balance is iron.

As to the effect of intermediate layer, the purpose of the intermediate layer is to reduce the effects of diffused alloy elements to the inner layer. The minimum strength of the intermediate layer has to be greater than 30kg/mm<sup>2</sup>. It is easy to break up in the junction between external layer and intermediate layer. The intermediate layer should have a high strength even if mixed with a fairly high amount of alloy. For these reasons, Adamite is the most appropriate material. The following is the chemical compositions of the intermediate layer and the reasons for the chemical composition ranges.

[0026]C: 1.0—2.5 wt %

High melting temperature will make it difficult to bond metallurgically when carbon is less than 1.0 wt %. On the other hand, when carbon is higher than 2.5 wt % the alloy will become very brittle.

Si: 0.2—3.0%

Silicon can de-gass and improve alloy fluidity.

[0027] Mn: 0.2—1.5 wt %

Mn: For the same reasons as in ductile iron to be limited in the above range

Ni less than 4.0 wt %.

Nickel can increase the strength of the alloy. However, the strengthening effect will saturate when nickel content is higher than 4.0 wt% and also increase the amount of residual austenite to reduce the strength.

[0028] Cr and Mo are less than 4.0 wt % each.

Cr and Mo can strengthen the alloy, however, both elements will have a negative effect if the content is greater than 4.0 wt%.

W, V, and Nb are less than 12 wt % in total.

These elements will inevitably enter into intermediate layer from external layer and the effects of these elements to the strength of intermediate layer are negligible. The upper limit of these elements is less than 12.0 wt % to avoid worsen mechanical property of the intermediate layer. Cobalt diffusion from external layer is inevitable and cobalt will not deteriorate the mechanical property of the intermediate layer, therefore, there is no limit to the cobalt content.

[0029] The rest of the intermediate layer is iron besides the above elements. However, P and S will embrittle the material and should control to the minimum level. In the present invention, similar to the inner material, both elements should be controlled within 0.2 wt %. The chemical composition of the external layer before pouring is listed below:

[0030]

C: 1.0—2.5 wt %, Si: 0.2-3.0 wt %, Mn: 0.2—1.5 wt %, P < 0.2 wt %, S < 0.2 wt %, Ni < 4.0 wt %, Cr < 4.0 wt %, Mo < 4.0 wt %, the rest is primarily the iron.

The design of containing 1.0-2.0 wt % carbon intermediate layer can also have the following effect besides reducing the harmful effect of alloy elements diffused from external layer.

[0031]

It is desirable to heat the external layer to above 1100 C in order to do austenizing heat treatment during quenching process. The heat reached to inner layer has to go through intermediate layer, so the temperature in the inner layer will be lower than 1100 C. Cr, Mo, W, and V will increase when the intermediate layer bonds with the external layer, but much lower than in external layer. However, the alloy content in diffusion zone between the intermediate layer and the inner layer will be much lower. Therefore, it is difficult to form carbide with the existence of the intermediate layer and also improve the diffusion zone strength.

[0032] In the intermediate layer in the present invention, most of the intermediate layer microstructure will change into Pearlite and the rest being Banite. Because there is no Martensitic transformation, there is less volume change and hence less residual stress in the composite roll. However, once the Martensite formed in the intermediate layer, there will be a huge compression residual stress formed with the Martensitic transformation in the external layer, resulting in the tensile damage of the inner layer.

[0033] It is well known that centrifugal casting process with permanent mold has been used to make composite roll. After casting the external layer or the required intermediate layer, the inner



layer is then poured statically. When making hollow composite roll, it is the best to use centrifugal casting method to form the inner layer. There are three types of centrifugal casting methods according to the shell shaped mold axis direction, vertical, horizontal, and angled. Each method is suitable to make composite roll.

[0034]

However, in horizontal centrifugal casting process, liquid metal will rotate up and down with the permanent mold, any off-centered roll and mold will cause harmful vibration, resulting in the movement of the solidified metal. Hence in thicker external layer roll it is easier to have composition segregation caused by shifting of the casting. Normally it is desirable to pour at temperature less than 70C above the solidification temperature. A thinner external layer would be better because of machining difficulty due to its high wear resistance in the present invention. The casting thickness of the external layer is 80 mm (designed at 55-70 mm), because of the chilling effect of the permanent mold, there will not be any chemical composition segregation issue even if pouring temperature is higher than pervious described. Moreover, the external layer thickness of the final composite roll, designed to be 25-40 mm, is 50 mm after taking off 20 mm in diffusion zone in the intermediate layer and another 10 mm for machining stock..

[0035] In the vertical centrifugal casting machine, the mold is fastened on the machine to avoid vibration. Hence in the vertical centrifugal process, a higher pouring temperature can be used without causing composition segregation.

[0036] The graphite containing high speed steel type cast iron roll in the present invention can be cooled from quenching temperature to 400-650 C to achieve excellent quenching microstructure. Only one tempering treatment is needed. In the austenizing process Mo, W, V, and Nb will be dissolved into matrix, these alloy elements will precipitate from the matrix in the form of fine carbides to create secondary hardening, resulting in a better high temperature hardness. On the other hand, graphite will also precipitate from the matrix during tempering process.

[0037] There are typically three different methods to heat up external layer of the composite roll for heat treatment; using a heating furnace to heat up the whole roll, or surface heating methods like using an induction coil to heat up the external layer of the roll, or using many natural gas burning nozzles to heat up the external layer. The bulk heating method requires a long heating cycle and also forms a thick oxide layer in the external layer. Moreover the temperature has to be limited below 1100 C to avoid melting the inner cast iron. The lower quenching temperature will cause carbides not being fully dissolved into matrix, resulting in a lower secondary hardening effect in the later tempering process.

[0038] The graphite containing high speed steel type cast iron in the present invention not only can be used for making composite rolls for cold or hot rolling, for making feeding rolls, but also can be used for making other roll shaped components.

[0039]

The actual examples are given below;

(1) Pouring liquid metal into a sand mold with 120mm in diameter and 120 mm in depth.

No. 1-9 are example alloys and No 10 is the previous high speed steel type alloy.

[0040]

[Table 1]

[0041]

(2) Making microstructure samples from each alloy, then measure graphite area under a microscope. The results are given in the same table. The graphite area in the sample alloys is between 3.9-5.1% while graphite is zero in the previous high speed steel.

[0042]

[table 2]

[0043] (3) Heating up each sample to 1100 C then quenching these samples under forced air cooling condition, and then tempering at 540 C three times. We can find that the hardness is about the same in the inventive alloys and previous high speed steel. Therefore we would expect the inventive alloys have excellent wear resistance.

(4) Furthermore, frictional coefficient was determined experimental using friction testing samples made from each alloy. The frictional coefficient was determined by measuring the torque from rotating a pair of V-shaped samples. The V-shaped material is S45C stainless steel and the results are given in table 2. As can be seen the frictional coefficient of the inventive alloys is lower than prior art by about 23-34%.

#### Example B

(1) Pouring external layer alloy into a centrifugal casting mold with 810 mm in diameter, samples No. 13 and No. 14 are taken after solidification is completed. The intermediate layer in the table is also made by centrifugal casting method. The amount of pouring metal is measured by the wall thickness of the roll, external layer is 70 mm, intermediate layer is 25 mm. Examples No. 11-No. 14 are all inventive samples.

[0044]

[table 3]

[0045]

(3) After rough machining the composite roll, pre-heat the roll at 600 C, then heat with natural gas with combustion nozzles spaced at 250 mm horizontally. Rotate the roll during heating stage. Stop heating when the external layer reaches 1125 C and the inner layer is 900 C. The required heating time is 180 minutes. From thermal conduction data we can estimate that the junction temperature between external layer and inner layer is about 1030 C. After heating, cool the roll with sprayed water. When the surface temperature of the roll reaches 500 C, naturally cool the roll to room temperature. Temper the roll at 550 C for 20 hours twice. The hardness of the heat treated roll is given in the table. As can be seen in the table, the hardness of the external layer is high so the wear resistance should be excellent. The graphite area is about 4.5-5.0 % from metallographic measurement.

[0046]

[table 4]

[0047] (5) After precision machining, use ultrasound method to detect the metallurgical bonding condition and all junctions are excellent. Then cut the roll to exam the cross section of the roll, no composition segregation is observed. On

the other hand, analyze intermediate layer middle area and center of the inner layer, the results are given in table 5. It is clear that alloy elements from external layer diffuse into inner layer even when there is an intermediate layer.

[0048]

[table 5]

[0049] (6) Based on the above results, the inventive composite roll should have excellent wear resistance, good ductility, and also resist temperature rise in the roll.

[0050] Cr, Mo, W, Nb, and Fe form high hardness carbides in the matrix in the present invention of the graphite containing high speed steel type cast iron. Cobalt strengthens the matrix and also increases room temperature and high temperature hardness. In the specially defined ranges of C, Si, and Ni, graphite precipitates from the alloy, which can absorb impact energy, retard crack propagation; lower down friction coefficient, and improve heat resistance.

[0051] Composite roll having the above graphite containing high speed steel type cast iron as external layer material can fully utilize its excellent properties to reduce rolling load and friction heat, improve feeding rate, and retard crack propagation. Because of good thermal conductivity from graphite, the composite roll is also suitable for cold rolling roll. Using Adamite as intermediate layer material can significantly reduce alloy element to diffuse into inner layer, which improves the boundary strength. There is no martenisitic transformation in Adamite to have a high residual stress, which can prevent the inner layer from melting when austenizing the external layer.

[0052] Because the inner layer also uses flake graphite type grey iron, spherical graphite type ductile iron, or graphite steel, together with the excellent thermal conductivity from graphite containing external layer material, this makes the composite roll to have an excellent heat dissipation ability to avoid hot deformation during rolling. Furthermore, the much lower Young's Modulus of the Adamite can avoid overload by flattening the roll itself to have a better safety and anti-accident properties.